

# Human Factors Issues in Intersection Safety

Research indicates that driver error may be involved in 90 percent of all crashes. While advances in automotive safety and highway design continue to improve, the one component that engineers and designers have very little control over is the driver. Understanding how drivers and all roadway users interact within an intersection environment is fundamental to improving roadway safety and saving lives.

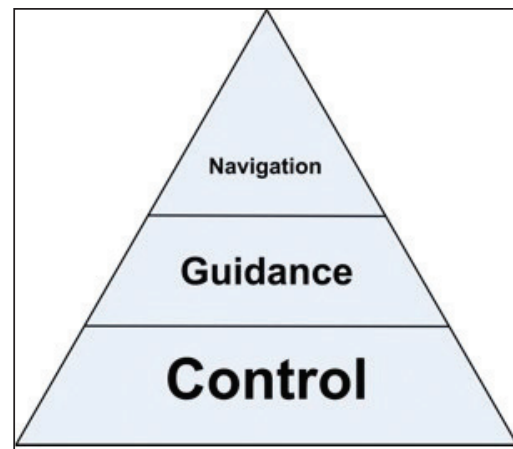
## The Driving Task

The overall driving task consists of many smaller tasks that a driver must perform at the same time. The three major subtasks include control, guidance, and navigation, as shown in Figure 1. Control relates to the physical operation of a vehicle. Guidance refers to interacting with other vehicles, for example following, passing, merging, and other actions such as following traffic control devices. Navigation refers to the driver choosing a route from origin to destination by reading guide signs and using landmarks. When a driver is overloaded with information, the driver actively sheds the information load by ignoring the navigational level in order to maintain the physical control of the vehicle and keep from colliding with another vehicle or other hazard when negotiating an intersection.

## Driver Attention and Decision Making

Negotiating intersections is one of the most complex and demanding tasks a driver faces. To successfully execute a vehicle maneuver through an intersection, the driver must receive and recognize available information, make a decision, and execute the desired action. One limitation is that humans are serial processors, and the cognitive task load at intersections can be quite large. Common items a driver must consider when approaching an intersection include the following:

- Being aware that an intersection is ahead.
- Monitoring and adjusting speed.
- Maintaining lane position.
- Being aware of other vehicles and objects in the environment, including the travel path.
- Being aware of other users, such as pedestrians and bicyclists in the intersection.
- Monitoring other traffic movements particularly in conflicting movements.
- Attending to signals or signs.
- Assessing adequacy of gaps for turning movements.
- Rapidly making a stop/go decision in the dilemma zone.
- Slowing for a turn and decelerating for a stop.
- Maintaining proper lane position.
- Selecting the proper lane.



**Figure 1. Levels of the Driving Task**  
Source: Lunenfeld, H. and Alexander, G.J. *A User's Guide to Positive Guidance*, 3rd Edition. Washington, DC: FHWA, 1990.

Given the short time drivers have to process a large amount of information, it is imperative that designers and engineers provide clear and accurate information to drivers to



U.S. Department of Transportation  
**Federal Highway Administration**



**Safe Roads for a Safer Future**  
Investment in roadway safety saves lives

help them navigate an intersection. The ability for a driver to successfully accomplish that task is greatly impacted by their expectancies. When expectancies are reinforced, drivers respond quickly and correctly and in predictable ways. However, if they encounter unfamiliar situations when approaching an intersection (e.g., missing or obscured traffic control devices, poor sight distance, unfamiliar lane assignments, lack of advance notice of the intersection, unusual intersection alignment), their responses may take longer to initiate and errors may result. Thus, it is essential to design consistency into intersections to minimize the likelihood of errors.

Vision is the most important information reception characteristic of drivers. Features of human vision are tied to specific roadway design elements as illustrated in Table 1.

## Driver Error

Perceptual failures account for a large portion of driver errors. These can include such items as “looked but did not see,” visual obstructions and clutter, reduced visibility due to environmental factors, poor judgment of speed and/or distance, and low conspicuity of target. Also, drivers are estimated to engage in potentially distracting secondary tasks nearly 30 percent of the time their vehicles are moving. These distractions (e.g., conversation with passengers, eating, cell phone use, texting, and so forth), increase the likelihood of driver error. According to a 2006 study by the National Highway Traffic Safety Administration: “Almost 80 percent of all crashes and 65 percent of all near-crashes involved the driver looking away from the forward roadway just prior to the onset of the conflict.<sup>1</sup> Prior estimates related to ‘distraction’ as a contributing factor have been in the range of 25 percent.” Misinterpretation of information and driver impairment are also major contributing factors to

1. The 100-Car Naturalistic Driving Study: Phase II – Results of the 100-Car Field Experiment, National Highway Traffic Safety Administration, Report No. DOT-HS-810-593.

driver error. Additionally, intersections themselves present their own unique set of driver errors, depending on the type of intersection at hand.

## Signalized Intersections

Common driver errors include the following:

- Failing to detect a signalized intersection and signal indications.
- Failing to detect proper lane assignment.
- Not understanding whether to proceed or stop at the onset of a yellow indication (this is known as the dilemma zone).
- Underestimating the time to reach an intersection.
- Underestimating the time to make a smooth stop.
- Failing to discern conflict boundaries (stop bar and beyond).
- Accepting an unsafe gap distance when making an unprotected left turn.
- Misinterpreting guide sign information.

## Unsignalized Intersections

Common driver errors include the following:

- Failing to detect the intersection.
- Accepting an unsafe gap distance.
- Inaccurately estimating approaching vehicles’ speed, also known as closure rates.
- Underestimating the time to accelerate to clear opposing traffic.
- Running a STOP sign.
- Failing to yield the right of way.



**Figure 2: Scanning for pedestrians, bicyclists, people in wheelchairs and blind or visually impaired people**



**Figure 3: Turn path markings help drivers maintain proper lane positioning**

## Roundabouts

Common driver errors include the following:

- Failing to control speed on approach.
- Failing to stop behind a queued vehicle at a roundabout approach.
- Accepting an unsafe gap distance.
- Failing to detect proper lane assignment for desired exit.
- Failing to yield the right of way to vehicles in the roundabout.
- Failing to yield to pedestrians and bicyclists legally in the roundabout.

**Table 1: Human Vision Characteristics as Related to Roadway Elements**

Visual Characteristic	Related Roadway Element(s)
Visual Acuity. Ability to see small details clearly.	Sign size; reading distant traffic signs
Contrast Sensitivity. Seeing objects that are similar in brightness to their background.	Pavement markings and delineation; detection of dark clothed pedestrians at night
Color Vision. Discrimination of different colors.	Sign, signal, and pavement marking design and retroreflectivity
Visual Field/Peripheral Vision	Sign placement, signal placement; seeing a bicycle approaching from the left; seeing pedestrians at the intersection
Scan Patterns	Sign and signal placement, delineation treatments
Motion Judgment/Angular Movement. Seeing objects moving across the field of view.	School zones and other crosswalks, highway railroad crossings; Judging the speed of cars crossing our path of travel
Movement in Depth. Detecting changes in visual image size.	Judging the speed of an approaching vehicle
Visual Illusions	Guide signs, pavement markings
Depth Perception. Judgment of the distance of objects.	Passing on two-lane roads with oncoming traffic
Eye Movement. Changing the direction of gaze.	Scanning the road environment for hazards
Glare Sensitivity. Ability to resist and recover from the effects of glare.	Reduction in visual performance due to headlight glare

## Design Considerations

Design policy implicitly incorporates principles of human factors. The American Association of State Highway and Transportation Officials (AASHTO) Green Book design criteria assume that the “design driver” is alert and in control of physical and mental abilities, has a reasonable ability to see and perceive the roadway environment, and has reasonable motor skills to enable steering, braking, and other operations. Table 2 summarizes key human factor considerations and their relationship to design elements.

## Engineering Solutions

Humans are not perfect when making decisions, and some errors in judgment are inevitable. However, steps can be taken to help reduce the likelihood that driver errors will take place. Therefore, intersection design and features are important and should take the limitations of human performance into account.

Drivers perform best under moderate levels of driver workload, while they make more errors under low- or high-workload environments. To achieve moderate driver workload conditions, apply the two guiding principles of intersection design and operation: Clarify and simplify.

Clarify means that the approaches to intersections are readily visible to the driver as they relate to configuration, lanes, and type of traffic control. Simplify means that the driver workload is at a medium level and never at a high level. This is accomplished by separating the actions of the driver approaching an intersection as follows and as illustrated in Figure 4:

- “Alert” the driver of the intersection ahead.
- Inform the driver of the routes and their turns at the intersection ahead.
- Inform the driver of the lane assignments ahead consistent with the route turns.
- Inform the driver of guide sign information for destinations (white on green guide signing).

- Ensure that only the STOP/YIELD action or signal indication decision is to be made by the driver in the last several hundred feet approaching the stop bar.

A significant proportion of intersection crashes involve left turns. Older drivers in particular run the greatest risk of being involved in a left-turn crash, due in part to their diminished ability to judge closure rates of oncoming vehicles. Using alternative intersection designs for left-turn lanes can help alleviate this problem. For example, a positive offset design can help improve visibility of oncoming vehicles. Adding protected left-turn phases can also assist drivers in turning movements.

Other elements of the intersection can be added or modified to improve driver performance and reduce the likelihood of errors. Some include the following:

- Using advanced guide signs, possibly with flashers, placed in conspicuous locations.
- Using large pavement markings and scribing path markings for multiple turn lanes.

**Table 2: Human Factors and Their Relationship to Roadway Design Elements**

Human Factor	Design Value	Design Element Affected
Perception-reaction time	1.0–2.5 sec.	Stopping Sight Distance
Deceleration rate	11.2 ft./sec. <sup>2</sup>	Stopping Sight Distance
Pre-maneuver. Distance for driver to detect an unexpected condition.	3.0–9.1 sec.	Decision Sight Distances
Gap acceptance. Turning left or right from stop. Crossing from stop	7.5 sec. (left turn) 6.5 sec. (right turn)	Minimum Stopping Sight Distance
Driver height of eye	1,080 mm	Stopping Sight Distance
Pedestrian walk times	3.0–4.5 ft./sec.	Pedestrian Facilities

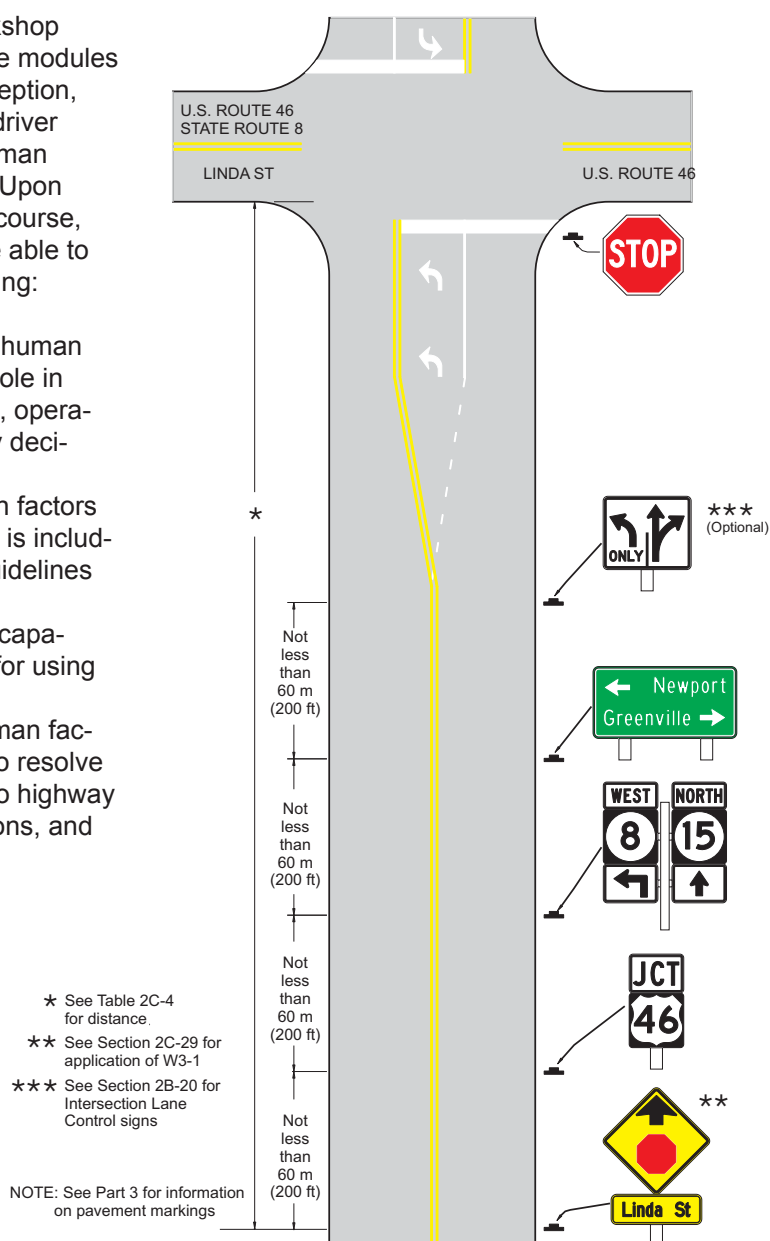
- Improving signal visibility by using larger 12-in. LED signals or beacons, signal back plates, or dual-red indications.
- Reducing the size of the dilemma zone with appropriate advanced detection.
- Ensuring that the intersection is free of visual obstructions, including parked vehicles, trees, and other roadside furniture so drivers have better views of vehicles operating on the side streets.
- Placing signal indications centered for each through lane to optimize the visibility of the signal indication.
- Ensuring lighting along the approaches and at the intersection is adequate.
- Avoiding permissive right-turn-on-red when intersection skew angle is less than 75 degrees.
- Adding protected-only left-turn phasing if appropriate.
- Enhancing pedestrian crossings through the use of high-visibility markings, beacons, and/or refuge islands.
- Exploring treatments to reduce speeds on the approaches of intersections.

This one-day workshop includes interactive modules on information reception, decision-making, driver responses and human factors principles. Upon completion of the course, participants will be able to perform the following:

- Recognize that human factors have a role in highway design, operations and safety decisions.
- Describe human factors information that is included in today's guidelines and standards.
- Identify human capabilities needed for using roadways.
- Apply basic human factors principles to resolve issues related to highway design, operations, and safety.

## Training

National Highway Institute Course: Human Factors for Transportation Engineers. For further information, contact FHWA, Office of Safety, at 202-366-2288.



**Figure 4. Intersection Layout Illustrating Concepts of Clarify and Simplify**



Institute of Transportation Engineers  
Introduction to Human Factors (Web seminar)

Please contact the Professional Development Division at 202-289-0222 for further information.

A summary of the course follows:

Provides an introduction to the field of human factors as it relates to human behavior, roadway design, and safety, as well as human characteristics as they relate to the driving task. The Web seminar will review demographic and environmental influences on driver behavior.

## Resources

American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets, Fourth Edition*. Washington, DC: AASHTO, 2004.

Institute of Transportation Engineers. *Traffic Engineering Handbook, 5th Edition*. Washington, DC: ITE, 1999.

NCHRP Report 500, Volume 5: *A Guideline for Addressing Unsignalized Intersection Collisions*. Washington, DC: TRB, 2003.

NCHRP Report 500, Volume 9: *A Guide for Reducing Collisions Involving Older Drivers*. Washington, DC: TRB, 2004.

NCHRP Report 500, Volume 10: *A Guide for Reducing Collisions Involving Pedestrians*. Washington, DC: TRB, 2004.

NCHRP Report 500, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections*. Washington, DC: TRB, 2004.

NCHRP Report 500, Volume 18: *A Guide for Reducing Collisions Involving Bicycles*. Washington, DC: TRB, 2008.

Dewar, R. and Olson, P. *Human Factors in Traffic Safety, Second Edition*, Lawyers & Judges Publishing, Tucson, AZ, 2007.



**Figure 5: Using pedestrian refuge islands when possible to provide a common and consistent location for drivers to look for pedestrians**

Shinar, David. *Traffic Safety and Human Behavior, First Edition*, Elsevier Science, Amsterdam, 2007.

*Highway Safety Manual, First Edition*. Washington, DC: TRB, To be published.

Lunenfeld, H. and Alexander, G.J. *A User's Guide to Positive Guidance, 3rd Edition*. Washington, DC: FHWA, 1990.

NCHRP Report 600A: *Human Factors Guidelines for Road Systems, Collection A: Chapters 1, 2, 3, 4, 5, 10, 11, 13, 22, 23, 26*. Washington, DC: TRB, 2008.

*Driver Distraction: A Review of the Current State-of-Knowledge*. Report No. DOT-HS-810-704. Washington, DC: NHTSA, 2008.

NCHRP Report 572: *Roundabouts in the United States*. Washington, DC: TRB, 2007.

*Roundabouts: An Informational Guide*. Report No. FHWA-RD-00-67, Washington, DC: 2000.

*The 100-Car Naturalistic Driving Study: Phase II – Results of the 100-Car Field Experiment*, National Highway Traffic Safety Administration, Report No. DOT-HS-810-593.



U.S. Department of Transportation  
**Federal Highway Administration**



**Safe Roads for a Safer Future**  
*Investment in roadway safety saves lives*